Journal of Artificial Intelligence and Capsule Networks (ISSN: 2582-2012)
www.irojournals.com/aicn/

# Probabilistic Neural Network based Managing Algorithm for Building Automation System


## Subarna Shakya

Professor, Department of Electronics and Computer Engineering, Central Campus, Institute of Engineering, Pulchowk, Tribhuvan University, Pulchowk, Lalitpur, Nepal

**E-mail:** drss@ioe.edu.np



### Abstract

A building automation system is a centralized intelligent system, which controls the operation of energy, security, water, and safety by the help of hardware and software modules. The general software modules employed for automation process have an algorithm with pre-determined decisions. However, such pre-determined decision algorithms won't work in a proper manner at all situations like a human brain. Therefore a human biological inspired algorithms are developed in recent days and termed as neural network algorithms. The Probabilistic Neural Network (PNN) is a kind of artificial neural network algorithm which has the ability to take decisions same as like of human brains in an efficient way. Hence a building automation system is proposed in the work based on PNN for verifying the effectiveness of neural network algorithms over the traditional pre-determined decision making algorithms. The experimental work is further extended to verify the performances of the basic neural network algorithm called Convolution Neural Network (CNN).


**Keywords:** Smart building, PNN, linked data, building management, neural network automation

## 1. Introduction

A building automation system is a combination of monitoring and controlling work on different applications. Figure 1 represents the basic applications of a building automation system. The automation systems are employed for a building management to improve the operational efficiency and the systems are mostly applied with a wired connection between the control units and the microcontrollers. In recent years, due to the advancement of internet of things, the control units are communicated through a wireless medium in certain cases [1].


*DOI: https://doi.org/10.36548/jaicn.2021.4.001*
*Received: 15.09.2021, received in revised form: 25.10.2021, accepted: 11.11.2021, published: 22.11.2021*

However, the reliability of the wireless systems are not yet achieved as same as that of the wired system due to poor communication signal, transmission loss and security threats. In some cases the automation systems are placed with a monitoring unit for taking decisions with a human interference [2, 3], though the systems employed with neural network algorithms are fast and accurate than the human decisions.

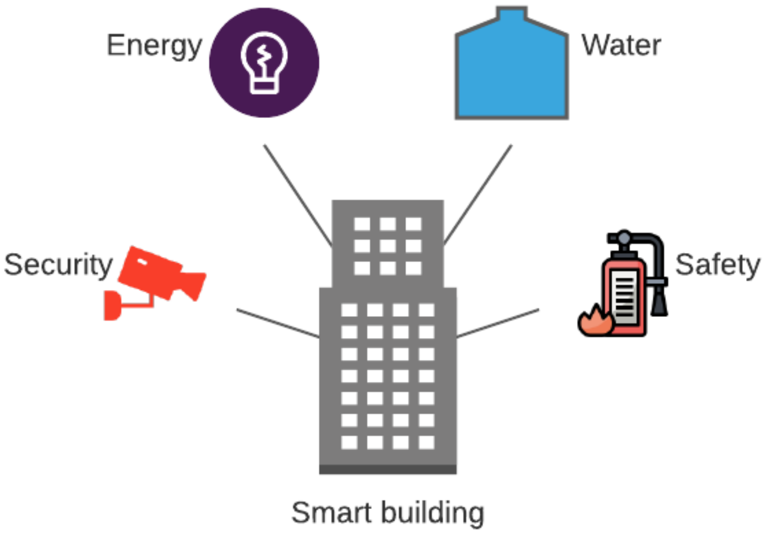



**Figure 1.** Applications of building automation system

Management of security, safety, water and energy are the primary tasks for a building automation system. Therefore the automation system requires different kind of sensors and control peripherals on each phase of the applications. Figure 2 represents a graphical summary of the tasks involved in a building automation system. Here the security systems have to be placed with a motion detection system for observing the abnormal activities on a floor or a room after working hours. The security system is also engaged in recent days with an access control, where the authorised persons can only enter into the building. Biometric sensors, passcode locks and electronic chips are used for such access control systems [4, 5]. In few cases, the security system is extended with an asset management system, where the movable asset locations are monitored with a bar code and ultrasonic sensors.

The energy management system is yet an important and most needed system in terms of saving the operational and maintenance costs of a building. The system requires to maintain the lighting efficiency at the required places with different intensities [6]. Similarly the system is also needed to estimate the energy demand requirement of the building on daily basis. To stabilize the lighting efficiency the systems are equipped with a Light Dependent Resistor

(LDR) to observe the change in light lumens of the present area. The energy demand estimations are helpful for the buildings managed with a solar photovoltaic system and generators. The energy demand estimations are carried out with the past and present data observations of the building on energy utilizations at various times [7].

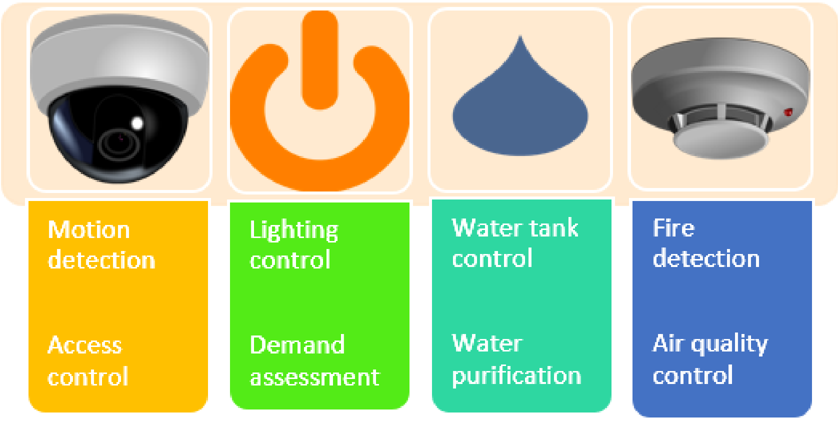



**Figure 2.** Summary of building management tasks

Automatic water pump operational systems are available in recent days for domestic applications with a floating sensor. Whereas, in smart building automation, the system is extended by managing multiple water tanks of the building with a single borewell or multiple borewell connection. To ensure the operational efficiency of the water management systems, the tanks are employed with leakage detection switches, continuous output level sensor, and infrared sensor along with a regular floating sensor. Automatic operation of water purification station is yet a difficult task in the management system, where the water hardness is measured with pH sensors to enable the process steps in the large scale water purifiers according to the observed pH levels [8, 9].

The building management systems are also equipped with a fire and smoke detection sensors for safety purposes and those sensors are connected with a water dispensing unit to activate in the emergency situations. The fire detection sensors are also inbuilt with a siren for enabling alert signal to the people available in such emergency places. The role of the building management is to specify the exact location of the fire on a multi-floor building. The system is also extended to operate the emergency gates at the critical situation. Generally, the safety management systems are also activated with an air quality control unit for observing the change in air quality of the building due to inadequate ventilation, bioaerosals and contamination from inside and outside of the building. To observe the air quality, the systems are equipped with different kind of sensors like $CO_2$, $NO_2$ and VOC sensors and the system will improve the air quality with proper air circulation, ventilation and exhaustion [10, 11]. The following section explores the attainments of the present systems on a building automation systems.

## 2. Literature Work

The automated control system operation can be split into three phases and it is shown in Figure 3. The first phase is monitoring phase, where the system to be controlled by a pre-determined algorithm is to be observed by the help of sensors and measuring instruments. The second phase is called analysing phase, where the system would take decision based on the algorithm placed into a microcontroller device. The third phase is called the control unit, where the control components like relays, actuators, solenoid valves will be operated by the control signals received from the microcontroller.

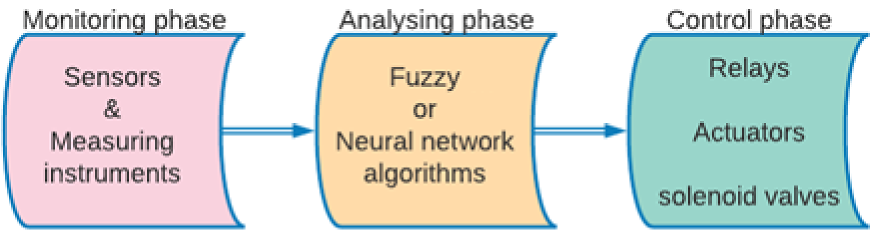



**Figure 3.** Phases of automated systems

A facility management-enabled building information model was designed to observe the mapping data from a building with the help of IoT sensors. The summarized data information are analysed with a visual programming language in cloud framework. Therefore the limitation on memory space requirement at the base station is avoided [12]. Apart from the IoT sensors, the cameras play a major role in the security purpose of a building management systems. The cameras are placed at some places for recognizing the human faces with a control system on unlocking the doors. Therefore the system requires multiple image of a person at different angles for training the face recognition algorithms [13]. In some cases the cameras are placed to identify the objects and their movement on specific locations. The cameras which are placed outside the buildings are connected with a robotic arm to move and focus on objects which are not clear to identify by the recognition algorithms [14].

The energy efficiency of a building automation system on Heating, Ventilation and Air-Conditioning (HVAC) system is verified in a simulation tool with virtual sensors for observing change in energy utilization at various stages of the HVAC system and the supply voltage. The change in supply voltage power and the individual stage power represents the fault presence in the HVAC system [15]. The system can be employed on real time application with the help of IoT sensors at the different stages of the HVAC system. As the energy and space requirement of the IoT sensors are very less, the HVAC system can be easily incorporated with the IoT modules [16]. Implementation of IoT sensors in critical locations are also made easy in smart cities with 5G mobile networks. Therefore the IoT modules can be placed anywhere, that has is a stable network connection along with a better cyber security system [17].

The data driven fault detection and diagnosis systems are very familiar in building automation system for regularizing its operation. The residual matrix and latent space matrix autoencoders were employed in a building management system for finding out the betterment among the approaches. The latent space matrix achieves 14.14% of better performances in the work on fault diagnosis step, whereas in fault detection step, there was no remarkable change observed between the two matrix approaches [18]. A bridge management system was designed to identify the change in strain of the construction while moving with heavy load vehicles. The experiment was carried out by employing a huge range of wireless sensors at various locations of the bridge for observing the change in strain at different time frame. The statistical analysis from the observed values are performed with machine learning algorithms like Recurrent Neural Networks (RNN) [19]. In recent days, the neural network algorithms are employed for many applications like imaging, data mining, prediction and estimations [20].

A passive rain water harvesting system was proposed in a green building without pump and additional electrical equipment. Based upon the statics of the building a silo point was determined in the approach to direct the unused rainwaters falling over the roof of buildings. A mathematical model was framed in the work by analysing the water pressure in the pipe line to reach the silo location with its loss and length analysis. The system avoids damage to the buildings by the stagnant waters at the rooftops [21]. The quality of drinking and general utilization water are need to be maintained with a specific pH levels for ensuring the healthy environment. Therefore a continuous water quality management system was developed with a cloud management application called ThingSpeak. As the Thingspeak application has the ability to interface with the android application, the control decision of the water process station can also be made with a mobile device [22]. The cloud computing techniques are also incorporated with the sensor and imaging devices in association with deep learning models for estimating the changes in the observed values and images based on their previous feature extraction model [23]. From the literature work it has been found that all the automated systems were associated with a microcontroller unit like Raspberry Pi and arduino for the peripheral connections [24]. The upcoming section explores the architectural view of a building management system with PNN algorithm.

## 3. Proposed Method

Probability theory based neural network algorithms are called as Probabilistic Neural Network (PNN). The PNN algorithm was developed to minimize the computational complexity of the traditional neural network algorithms. The classification and pattern recognition kind of applications are widely employed with the PNN model where the features available in the training samples are approximated with Probability Distribution Function (PDF). The non-parametric and Parzen window functions are also incorporated with the PDF on feature approximation process for estimating the class probability of the given input data. The network also utilizes the Bayes rule for minimizing the class misclassification by analysing the highest posterior probability of a given sample. The architecture of the PNN comprises of four layers in feed-forward connection starting from input layer, pattern layer, summation layer and decision layer. Figure 4 explores the graphical view of a PNN algorithm.

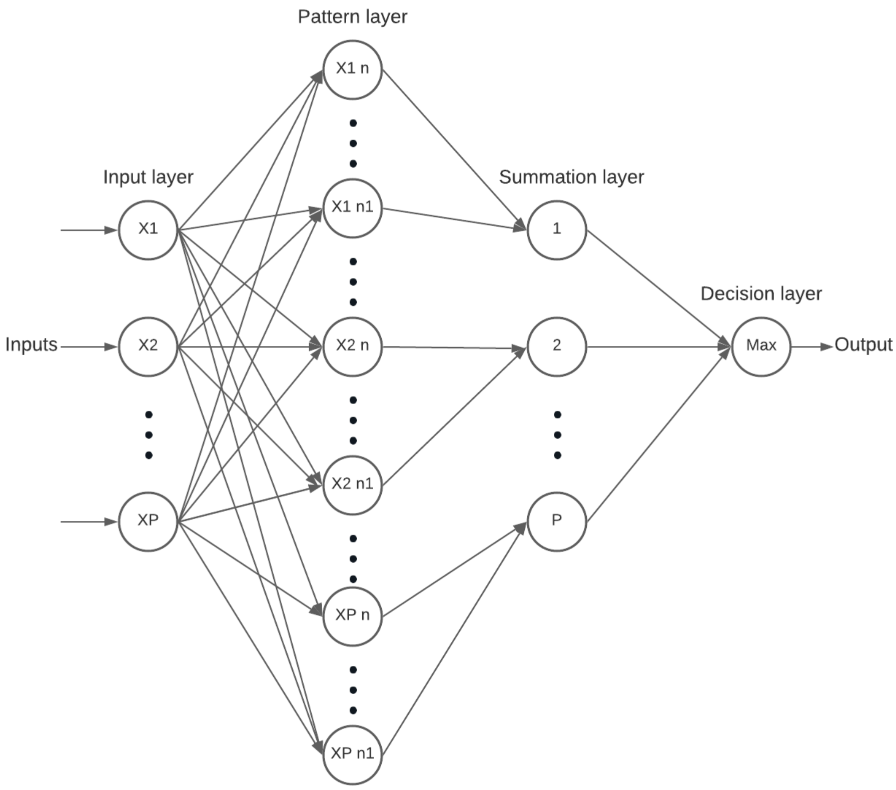



**Figure 4.** Architecture of PNN algorithm

The input layer starting from X1 to XP represents the formation of neurons estimated by the predictor variables of the input samples. The data standardization is analysed in the input layer by dividing the interquartile range from the subtraction of median input value. The motive of the pattern layer is to generate the neuron counts with respect to the actual class of data available in the input data. The values predicted from the case variables and the target values are placed in the neurons of the pattern layer. The Euclidean distance among the given test data and the trained data are calculated and placed inside the hidden neurons. The values which are stored in the pattern layers are operated with a sigma function to calculate the radial basis kernel function.

The summation layer is the formation of individual neurons for each category with their target variables. The weighted output value stored in the hidden layers are accumulated in the summation layer based on their category. The decision layer is placed at the final stage for comparing the values estimated in the summation layer on each category. The algorithm predicts the output by identifying the largest value output found among the respective pattern layers.

The proposed work employs the PNN algorithm for their support in taking several decisions in the building management system. Here the individual input neurons are created in the PNN algorithm for each categorical decisions in safety, security, water and energy managements. The inputs are assigned with numerical data collected from various sensors with their expected decisions on managing the control units. Therefore the algorithm manages the control unit same as that of human estimations in an efficient way. The overview of the proposed workflow is shown in Figure 5.

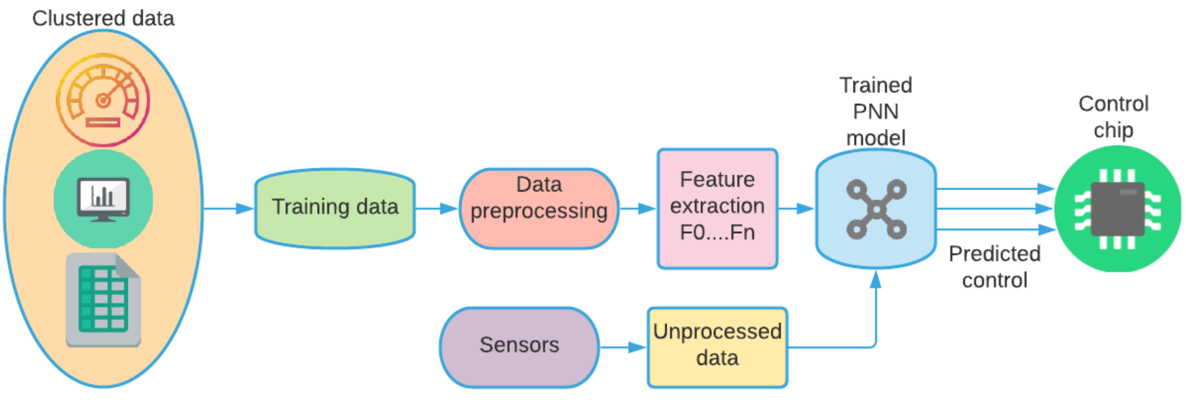
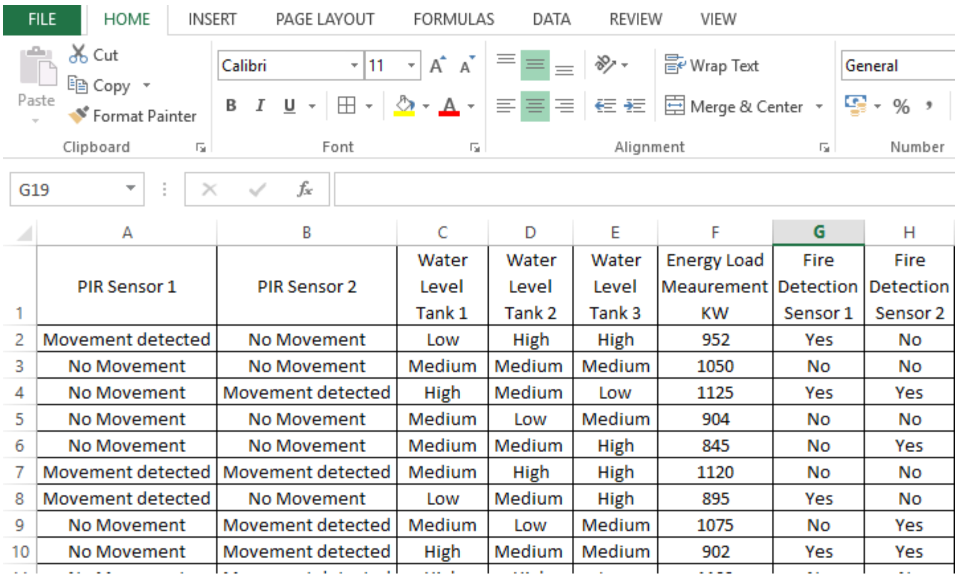



**Figure 5.** Workflow of the proposed model

The training data is the collection of values collected from various sensors available in the building management system. All such data are pre-processed in the work before forwarding it to the feature extraction process. The PNN model extracts the valuable information from the input data and creates individual neurons in their architecture for enabling various output predictions. Finally, the unprocessed data extracted from the real-time operational sensors are forwarded to the trained PNN model for generating the required control signal for the connected hardware components. The below section explores the performance betterment of the proposed model with the traditional CNN model and the predetermined control algorithms.

## 4. Experimental work

The experimental work on the proposed approach is employed with a self-made dataset consisting of readings taken from PIR sensor for the movement detection as security purpose and observed power values for the requirement of enabling generators during power shortage. The dataset is also collected by measuring the water tank level along with the fire detection sensor estimations. Figure 6 explores a sample view of the created dataset. The dataset comprises of 1000 individual data on each category for taking the decisions. The dataset split-up ratio followed for the training and testing process is 70% and 30%. The experimental projections on the accuracy of the proposed work along with the previous models are explored in Table 1.




| | PIR Sensor 1 | PIR Sensor 2 | Water Level Tank 1 | Water Level Tank 2 | Water Level Tank 3 | Energy Load Meaurement KW | Fire Detection Sensor 1 | Fire Detection Sensor 2 |
|---|---|---|---|---|---|---|---|---|
| 2 | Movement detected | No Movement | Low | High | High | 952 | Yes | No |
| 3 | No Movement | No Movement | Medium | Medium | Medium | 1050 | No | No |
| 4 | No Movement | Movement detected | High | Medium | Low | 1125 | Yes | Yes |
| 5 | No Movement | No Movement | Medium | Low | Medium | 904 | No | No |
| 6 | No Movement | No Movement | Medium | Medium | High | 845 | No | Yes |
| 7 | Movement detected | Movement detected | Medium | High | High | 1120 | No | No |
| 8 | Movement detected | No Movement | Low | Medium | High | 895 | Yes | No |
| 9 | No Movement | Movement detected | Medium | Low | Medium | 1075 | No | Yes |
| 10 | No Movement | Movement detected | High | Medium | Medium | 902 | Yes | Yes |

**Figure 6.** Dataset sample view

**Table 1.** Comparative analysis of the proposed model with the existing models

| Performance Metrics | Predetermined Algorithm | CNN | PNN |
|---|---|---|---|
| Accuracy | 88.72 | 93.85 | 96.92 |
| Precision | 98.83 | 98.9 | 98.93 |
| Recall | 89.42 | 94.71 | 97.88 |
| F1 Score | 93.89 | 96.76 | 98.4 |

The experimental setup is designed to operate the camera units only when there is a movement detection on a specific area through the PIR sensors. This reduces the huge space requirement in the hard disk for saving the unwanted informations. The system is also designed to manage the water pumps by estimating their level on individual tanks. The proposed design is employed with a three tank system connected to a sing borewell with a solenoid valve adjustment for transferring the water flow to the different tanks. In the same way, the energy optimization takes place for enabling the signal to operate the generators (two generators) connected to the load. The fire detection sensor location is considered for operating the necessary emergency exists to be operated at the specific time.

## Conclusion

Maintenance of a building is a huge and critical task that requires the co-ordination of many people. A simple error made by a human may affect the operation of the whole system to a certain extent. Therefore the sensor based control units were introduced few years ago. However, the sensors and the control units are independent in their operation on different locations and applications. It is always difficult to co-ordinate the sensors at different locations with a wired communication. Hence the IoT sensors are introduced to make a coordination between the sensor units connected on a single application. As the data produced by the sensors are huge in number, it requires an automatic monitoring and decision making algorithms. So, the building automation work discussed in the paper is employed with a PNN algorithm for operating the control units connected in the system with respect to their requirements. The experimental work indicates that the proposed model achieves the accuracy of 96.92% which is comparatively better than the traditional CNN and predetermined algorithms.

## References

[1] Patil, Prachu J., Ritika V. Zalke, Kalyani R. Tumasare, Bhavana A. Shiwankar, Shivani R. Singh, and Shailesh Sakhare. "IoT Protocol for Accident Spotting with Medical Facility." Journal of Artificial Intelligence 3, no. 02 (2021): 140-150.

[2] Al-Hadhrami, Yahya, and Farookh Khadeer Hussain. "DDoS attacks in IoT networks: a comprehensive systematic literature review." World Wide Web (2021): 1-31.

[3] Manoharan, J. Samuel. "A Novel User Layer Cloud Security Model based on Chaotic Arnold Transformation using Fingerprint Biometric Traits." Journal of Innovative Image Processing (JIIP) 3, no. 01 (2021): 36-51.

[4] Soewito, Benfano, and Yonathan Marcellinus. "IoT security system with modified Zero Knowledge Proof algorithm for authentication." *Egyptian Informatics Journal* 22, no. 3 (2021): 269-276.

[5] Sharma, Rajesh, and Akey Sungheetha. "An Efficient Dimension Reduction based Fusion of CNN and SVM Model for Detection of Abnormal Incident in Video Surveillance." Journal of Soft Computing Paradigm (JSCP) 3, no. 02 (2021): 55-69.

[6] Mariano-Hernández, D., L. Hernández-Callejo, A. Zorita-Lamadrid, O. Duque-Pérez, and F. Santos García. "A review of strategies for building energy management system: Model predictive control, demand side management, optimization, and fault detect & diagnosis." *Journal of Building Engineering* 33 (2021): 101692.

[7] Shakya, Subarna. "A Self Monitoring and Analyzing System for Solar Power Station using IoT and Data Mining Algorithms." *Journal of Soft Computing Paradigm* 3, no. 2 (2021): 96-109.

[8] Herrera, Axel, Giuliana D'Imporzano, Francisco Gabriel Acién Fernandez, and Fabrizio Adani. "Sustainable production of microalgae in raceways: Nutrients and water management as key factors influencing environmental impacts." *Journal of Cleaner Production* 287 (2021): 125005.

[9] Sungheetha, Akey, and Rajesh Sharma. "Fuzzy Chaos Whale Optimization and BAT Integrated Algorithm for Parameter Estimation in Sewage Treatment." Journal of Soft Computing Paradigm (JSCP) 3, no. 01 (2021): 10-18.

[10] Kim, Young-Jin, Hanjin Kim, Seunggi Lee, and Won-Tae Kim. "Trustworthy Building Fire Detection Framework With Simulation-Based Learning." *IEEE Access* 9 (2021): 55777-55789.

[11] Sungheetha, Akey, and Rajesh Sharma. "Real Time Monitoring and Fire Detection using Internet of Things and Cloud based Drones." Journal of Soft Computing Paradigm (JSCP) 2, no. 03 (2020): 168-174.

[12] Quinn, Caroline, Ali Zargar Shabestari, Tony Misic, Sara Gilani, Marin Litoiu, and J. J. McArthur. "Building automation system-BIM integration using a linked data structure." *Automation in Construction* 118 (2020): 103257.

[13] Kalturi, Amrutha, Anjali Agarwal, and N. Neelima. "Smart and Autonomous Door Unlocking System Using Face Detection and Recognition." In *Intelligent Data Communication Technologies and Internet of Things: Proceedings of ICICI 2020*, pp. 99-108. Springer Singapore, 2021.

[14] Chen, Joy Iong-Zong, and Jen-Ting Chang. "Applying a 6-axis Mechanical Arm Combine with Computer Vision to the Research of Object Recognition in Plane Inspection." Journal of Artificial Intelligence 2, no. 02 (2020): 77-99

[15] Song, Li, Gang Wang, and Michael Brambley. "Building Automation System Embedded HVAC System Energy Performance Degradation Detector." In *Automated Diagnostics and Analytics for Buildings*, pp. 563-574. River Publishers, 2021.

[16] Singh, Utkarsha, and Inderveer Chana. "Enhancing Energy Efficiency in IoT (Internet of Thing) Based Application." In *International Conference on Inventive Computation Technologies*, pp. 161-173. Springer, Cham, 2019.

[17] Smys, S., Haoxiang Wang, and Abul Basar. "5G Network Simulation in Smart Cities using Neural Network Algorithm." Journal of Artificial Intelligence 3, no. 01 (2021): 43-52.

[18] Choi, Youngwoong, and Sungmin Yoon. "Autoencoder-driven fault detection and diagnosis in building automation systems: Residual-based and latent space-based approaches." *Building and Environment* (2021): 108066.

[19] Paudyal, Amit, Nirdesh Bhattarai, Shiva Bhandari, Nabin Rai, Ram Prasad Rimal, and Nanda Bikram Adhikari. "A System of Vehicular Motion Sensing and Data Acquisition over Thapathali–Kupondole Bridge and Impact Prediction and Analysis Using Machine Learning." In *Proceedings of International Conference on Sustainable Expert Systems*, pp. 555-569. Springer, Singapore, 2021.

[20] Vijayakumar, T. "Comparative study of capsule neural network in various applications." Journal of Artificial Intelligence 1, no. 01 (2019): 19-27.

[21] Anand, Rishika, and Monika Choudhary. "Water Quality Monitoring for Horticulture and Aquaculture." In *International Conference on Intelligent Computing, Information and Control Systems*, pp. 345-356. Springer, Cham, 2019.

[22] Anand, Rishika, and Monika Choudhary. "Water Quality Monitoring for Horticulture and Aquaculture." In *International Conference on Intelligent Computing, Information and Control Systems*, pp. 345-356. Springer, Cham, 2019.

[23] Kumar, T. Senthil. "Video based Traffic Forecasting using Convolution Neural Network Model and Transfer Learning Techniques." Journal of Innovative Image Processing (JIIP) 2, no. 03 (2020): 128-134

[24] Mamunooru, Chidrupa Manogna, Suseendra Attada, Sai Vipanchi Kodali, Mohan Reddy Tumma, Santanu Kumar Dash, and Y. Padma Sai. "Smart Meter Using Raspberry Pi for Efficient Energy Utilization." In *Data Intelligence and Cognitive Informatics*, pp. 153-163. Springer, Singapore, 2021.

## Author's biography

**Subarna Shakya** is currently a Professor of Computer Engineering, Department of Electronics and Computer Engineering, Central Campus, Institute of Engineering, Pulchowk, Tribhuvan University, Coordinator (IOE) , LEADER Project (Links in Europe and Asia for engineering, education, Enterprise and Research exchanges), ERASMUS MUNDUS. He received MSc and PhD degrees in Computer Engineering from the Lviv Polytechnic National University, Ukraine, 1996 and 2000 respectively. His research area includes E-Government system, Computer Systems & Simulation, Distributed & Cloud computing, Software Engineering & Information System, Computer Architecture, Information Security for E-Government, and Multimedia systems.